



# **Automation of Space and Ground Inventory Management Systems**

**Consultative Committee for Space Data Systems  
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Patrick W. Fink, Ph.D. , Andrew Chu,  
Timothy F. Kennedy, Phong H. Ngo,  
Tim Brown, William Hartwell, Darryl Gaines  
(NASA-JSC)

Robert Stonestreet (Barrios Technology)

Kevin K. Gifford, Ph.D.  
(UC, Boulder)



# Overview

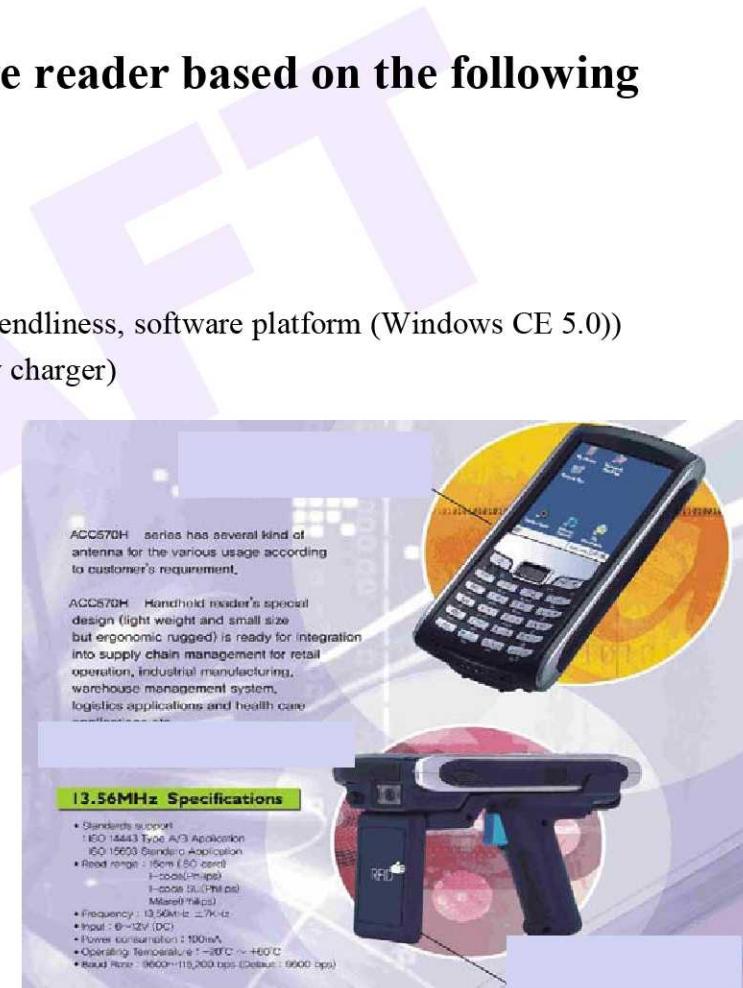
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- **Update on ISS handheld readers for inventory audits**
- **Integrated RFID over a Delay/Disruption Tolerant Network (DTN)**
  - Handheld RFID readers
  - RFID portal
  - RFID “Smart” Shelf
  - RFID Trash Receptacle
  - RFID Soft Stowage
  - RFID Application
- **RFID for Center Operations - Pilot Projects**
  - Space Vehicle Mockup Facility
  - Neutral Buoyancy Laboratory (NBL)
- **RFID Enclosures**



# BCR/RFID System Hardware

- **READER: ACC 570u**
- **Completed testing and assessments**
- **System 570 is the primary candidate reader based on the following considerations:**
  - Crew comments (form factor, display size)
  - Barcode reading accuracy
  - RFID reading accuracy
  - Functions and capabilities (power setting, user-friendliness, software platform (Windows CE 5.0))
  - Battery and battery charger (offers a multi-battery charger)
  - Successfully operated during parabolic flights





## BCR/RFID System Hardware

- **TAGS:**
- **Following types of tags have been selected as primary candidates:**
  - OMNI-ID 2-part Prox Tags (for metal, items with liquid)
  - Alien Technology Squiggle Tags in form factor 4" x 1" and 4" x 6" (for general uses such as zip-lock bags, CTBs, etc.)
  - All 3 of these tags uses the Alien Technology Higgs 3 integrated circuit.
  - Tags performed well in zero-g parabolic flight tests

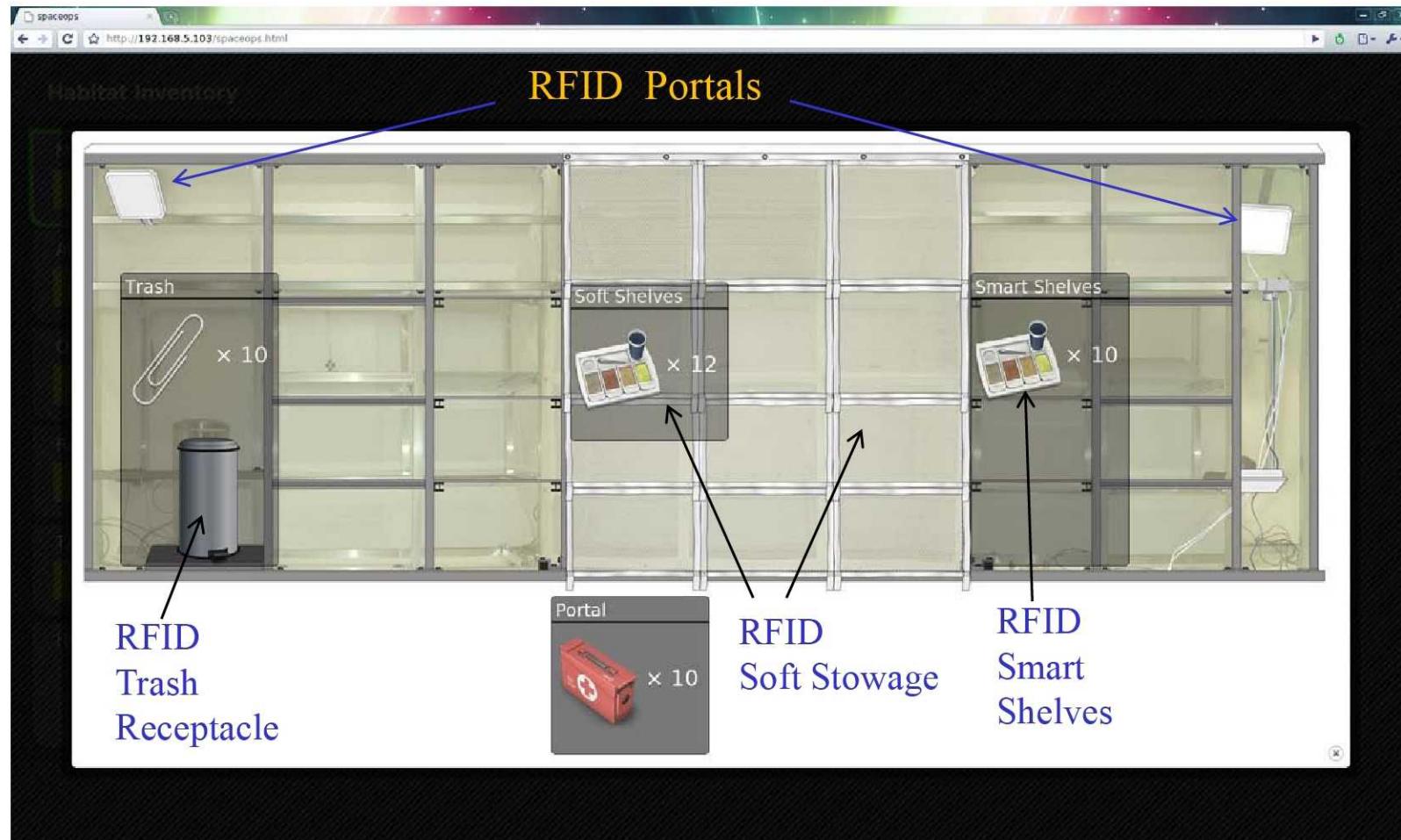




# **Integrated RFID over a Delay/Disruption Tolerant Network (DTN)**



# Integrated RFID Systems

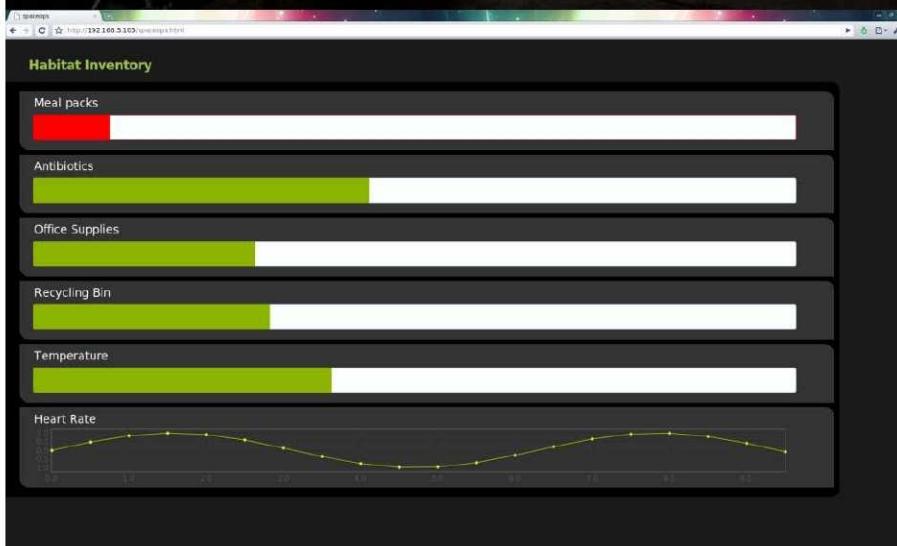




# Efficient and Autonomous Merging of Networks



- As the LER arrives to re-stock the habitat...
- LER WLAN network is discovered, and...
- Habitat and LER inventories are displayed

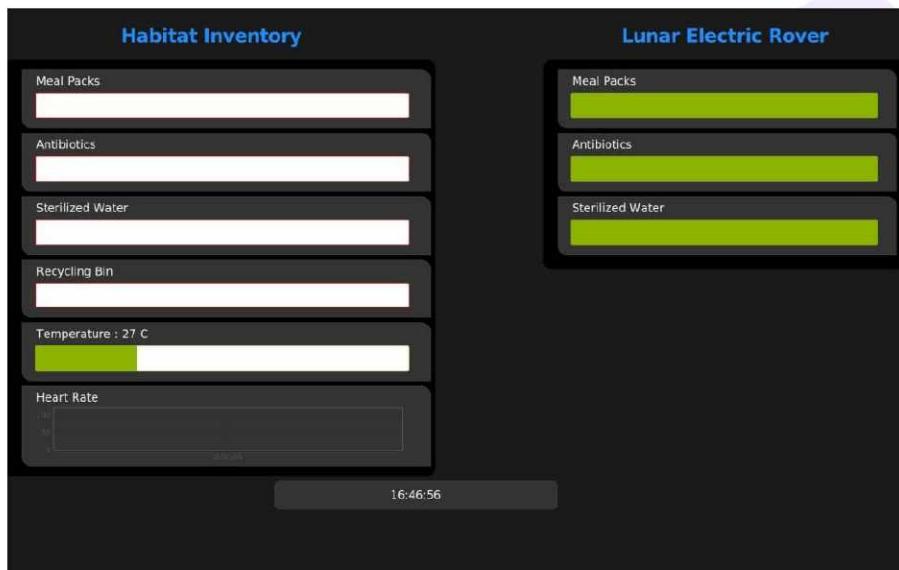




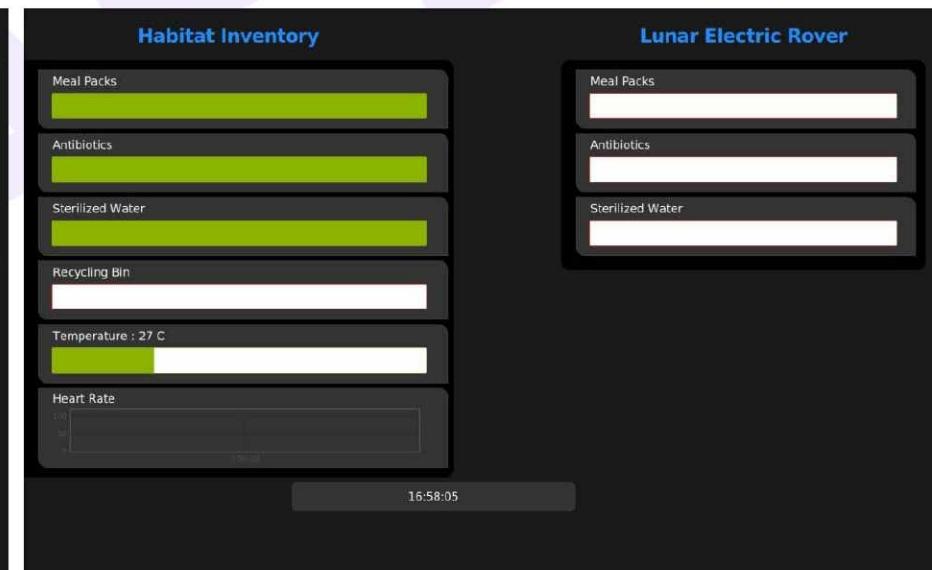
# Inventory Transfer Test

**Inventory is transferred from the LER to the Habitat.**  
**LER portal and Habitat RFID systems capture transfer.**  
**Inventory management screens are updated.**

**Before**



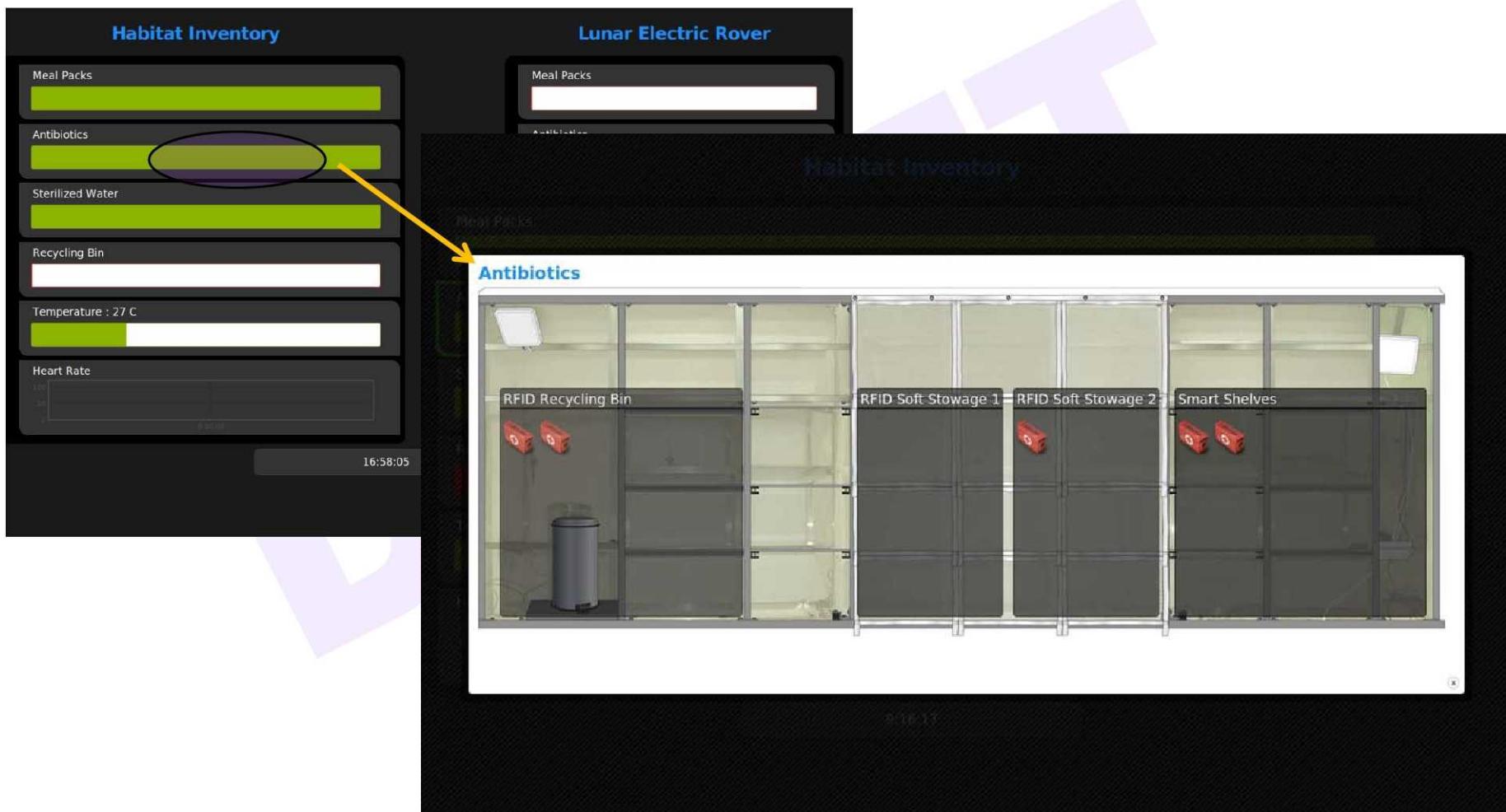
**After**





## Inventory “Drill-Down”

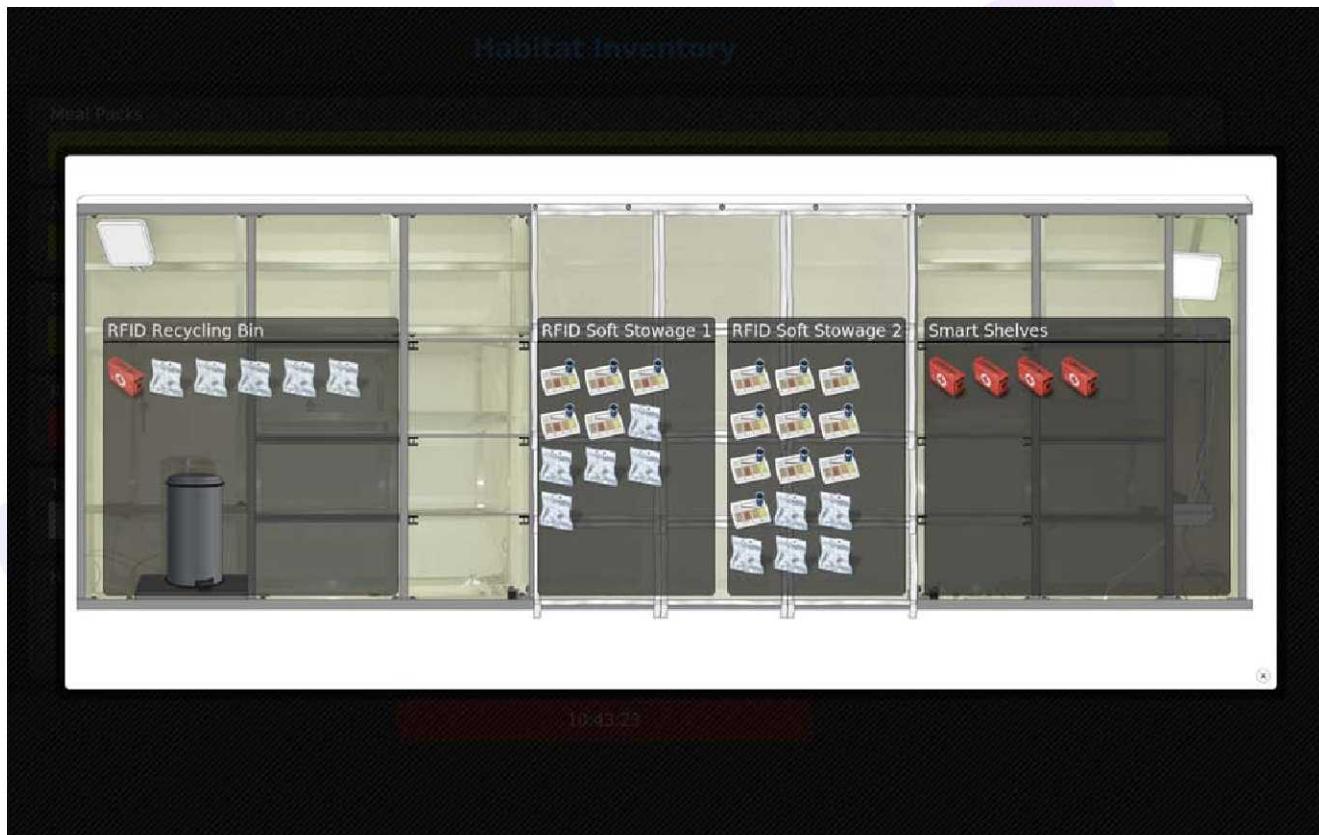
Clicking on any inventory bar brings up quantities and known locations.





## Showing Contents of Locations

The application can also show contents of all storage locations.





# Inventory Management Applications over DTN Network

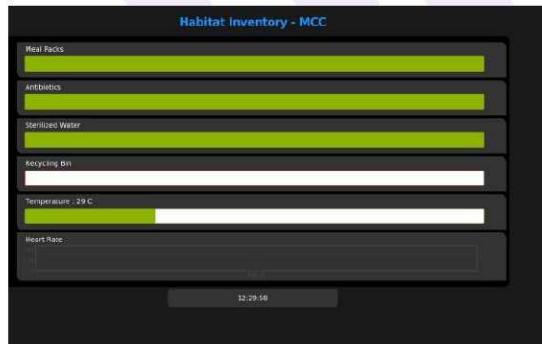
## Control Center Inventories Automatically Refreshed Following Disruption

### Habitat Display



Databases synchronized

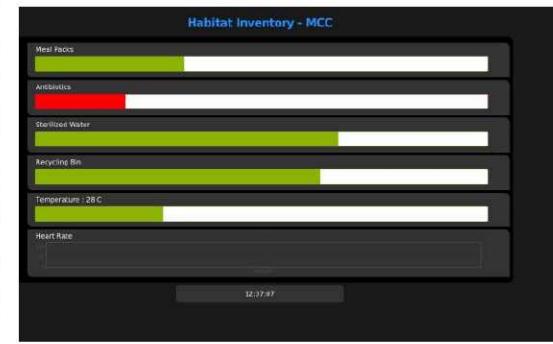
### MCC Display



Link disrupted,  
MCC display becomes “stale”



Link restored,  
MCC display updates  
automatically





## **RFID for Center Operations - Pilot Projects**



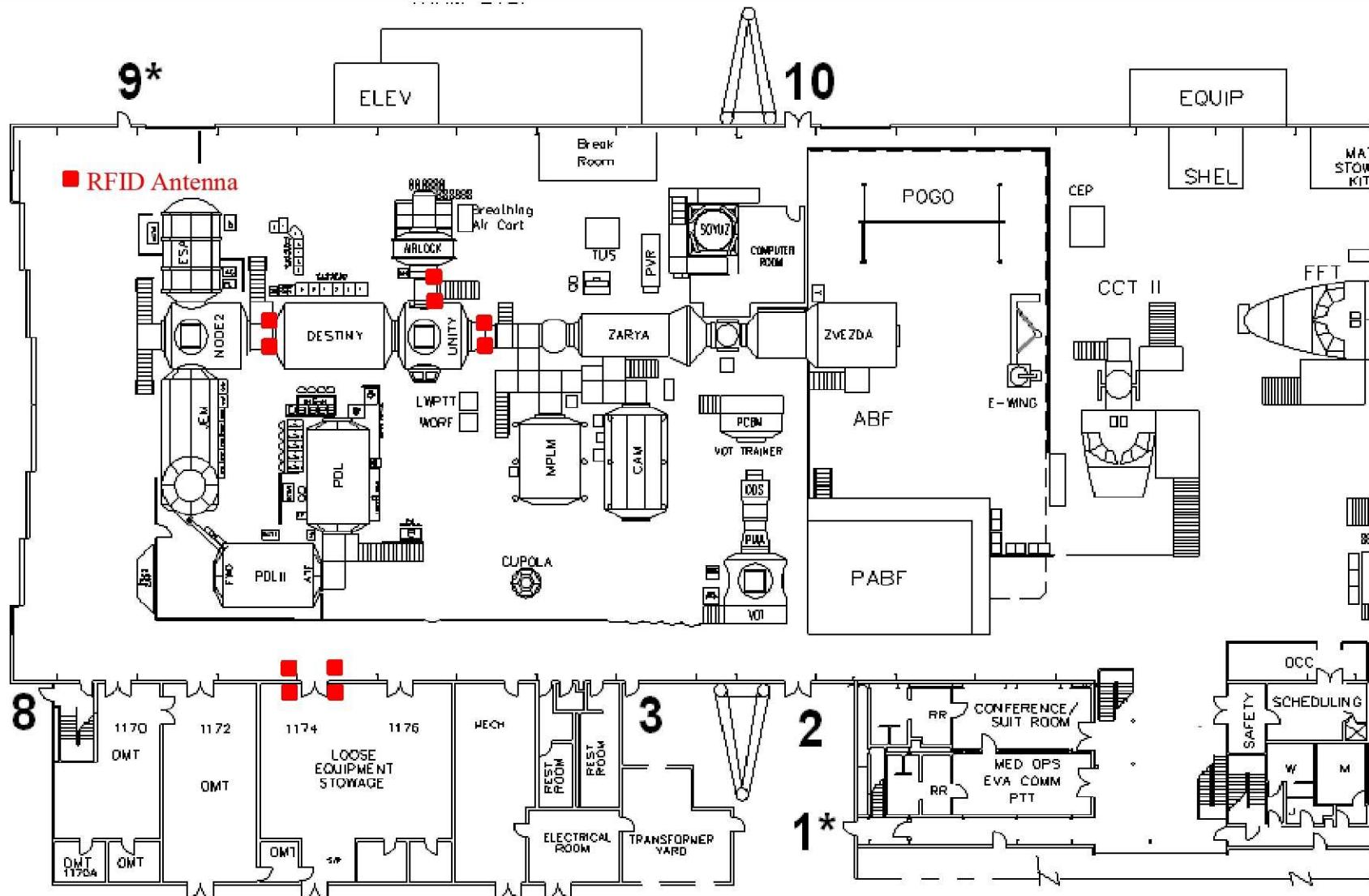
## RFID Pilot: Targeted Area #1 - SVMF

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- **Description**
  - Track movement of items from 3 classes (EVA prep/post, Emergency, Habitation Procedures) as tagged items enter or exit the loose equipment stowage room and Lab/Node 1/Airlock modules
- **Benefits**
  - Particularly relevant as an ISS RFID inventory management test bed
  - Easy to modularize for reduced-scope study; i.e., limited entry/exit
  - Easy to scale for full operational deployment
  - University partner running concurrent RFID experiments in SVMF (University of Nebraska-Lincoln)



# RFID Pilot: Targeted Area #1 - SVMF





# RFID Pilot: Targeted Area #2 – Neutral Buoyancy Lab (NBL)

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- **Description**

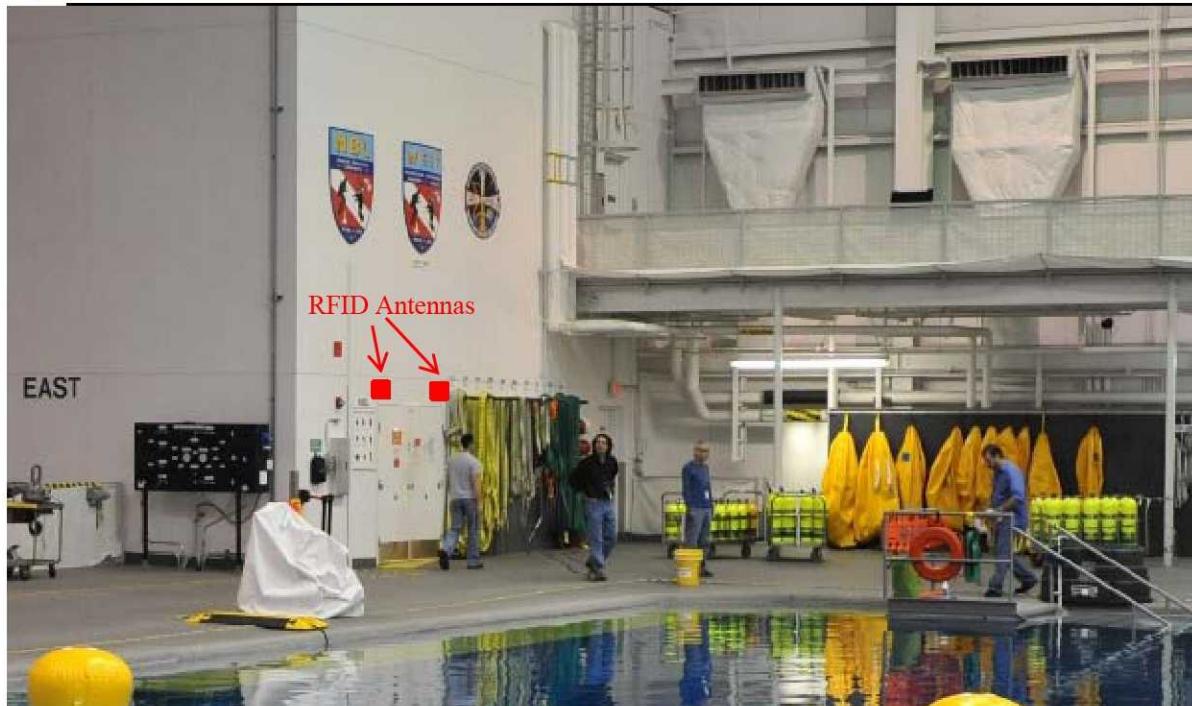
- Track 1000's of tools, parts, and mockups into and out of the NBL pool
- Multi-warehouse environment, complex scattering environment
- Many entries and exits with large high-bay doors
- Focus for pilot: track scuba tanks as they come in and out of elevator at 1<sup>st</sup> and 2<sup>nd</sup> floors

- **Benefits**

- Even limited scope of scuba tanks will provide inventory management time savings
- Scuba tanks traverse the same path with limited entry/exit points
  - Easy to track with two portals



## RFID Pilot: Targeted Area #2 - NBL



## RFID Enclosures

- Tested in various forms: trash receptacles, soft stowage, CTB carriers
- Read accuracies typically are  $> 95\%$ , and are often near 100%
- Additional advantage compared to handheld interrogators: less likely to read tags in the surrounding environment; e.g., tags in other CTBs



**RFID Trash Container**

## CTB in RFID Enclosure



## Conclusion/Forward Work

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- **ISS is moving forward with first operational RFID system for inventory audits**
  - Optical barcode scanning functionality is still retained
- **Integrated RFID system used to track transfers of tagged items over DTN network**
  - Control center displays are updated automatically upon restoration of a disrupted communication link
- **Several pilot programs underway for Center ground operations**
- **RFID Enclosure found to be highly accurate**
  - Benefits:
    - confines reads to interior tagged items
    - Less likely to cause interference to other systems



# Backup



## ISS Inventory Management Present State

- ~ 10,000 items are tracked with the Inventory Management System (IMS) software application
- Hand-held optical barcode reader used for inventory audits
- Crew/Cargo Transfer Bags must have Ziploc bag contents removed, audited, replaced:
  - ~ 20 mins crew time,
  - 1 CTB/crew/day
- ~ 500 CTBs on ISS at any given time (2008)

Cargo Transfer Bags (CTBs)





# RFID Space Inventory Introduction: Handheld Readers

- **Handheld RFID readers are likely to be the first operational RFID system on ISS**
  - Will have dual barcode capability, also, to facilitate transition
- **Read accuracies < 100% for single CTB read, but fairly effective when reader scanned or “painted” around CTB exterior**
- **Requires 20s/CTB read and little vehicle infrastructure (battery powered with 802.11 capability)**
- **Tested on CTBs (10in. x 17in. x 9.5in) containing tagged Ziplock bags filled with tagged personal items (52 tags total)**
- **Tested on Ambulatory Medical Packs (AMPs - 12.5in. x 24.5in. x 8in.) with sub-kits filled with tagged pharmaceutical items (330 tags total)**





# Handheld RFID Reader Evaluation

Four commercially available readers tested by five different individuals (I1-I5):

CTB tags  
(52 tags total)

	I1	I2	I3	I4	I5	average	%
<b>Reader 1 30 dBm</b>	48	48	49	48	48	48.2	92.7%
<b>Reader 2 28 dBm</b>	48	48	47	48	47	47.6	91.5%
<b>Reader 3 30 dBm</b>	42	42	44	45	43	43.2	83.1%
<b>Reader 4 30 dBm</b>	48	48	48	49	48	48.2	92.7%

AMP tags  
(330 tags total)

	I1	I2	I3	I4	average	%
<b>Reader 2 28 dBm</b>	267	264	266	263	265	80.3%
<b>Reader 3 30 dBm</b>	122	125	130	120	124.3	37.7%
<b>Reader 1 30 dBm</b>	281	276	282	280	279.8	84.8%
<b>Reader 4 30 dBm</b>	245	239	238	226	237	71.8%

# Portal-based RFID Inventory Management

- More automation desired for viable RFID inventory system
- Portal-based interrogator reads CTBs entering/exiting habitat
- Requirements:
  - High read accuracy
  - Low power (→ triggered operation)
  - Tag directionality determined
- Four antenna system (two external, two internal) implemented in habitat mockup
- Pressure pad on porch used to trigger tag reads





# RFID Portal Evaluation

- CTB (52 tagged items) carried on left, right, and in front of test subject
- Reader tested in “continuously on” and “triggered” modes
- Transmit power of 30 dBm used for all tests
- CTB carried starting 40 feet out, pressure mat mounted five feet out
- Results averaged over five trials

accuracy vs.  
position

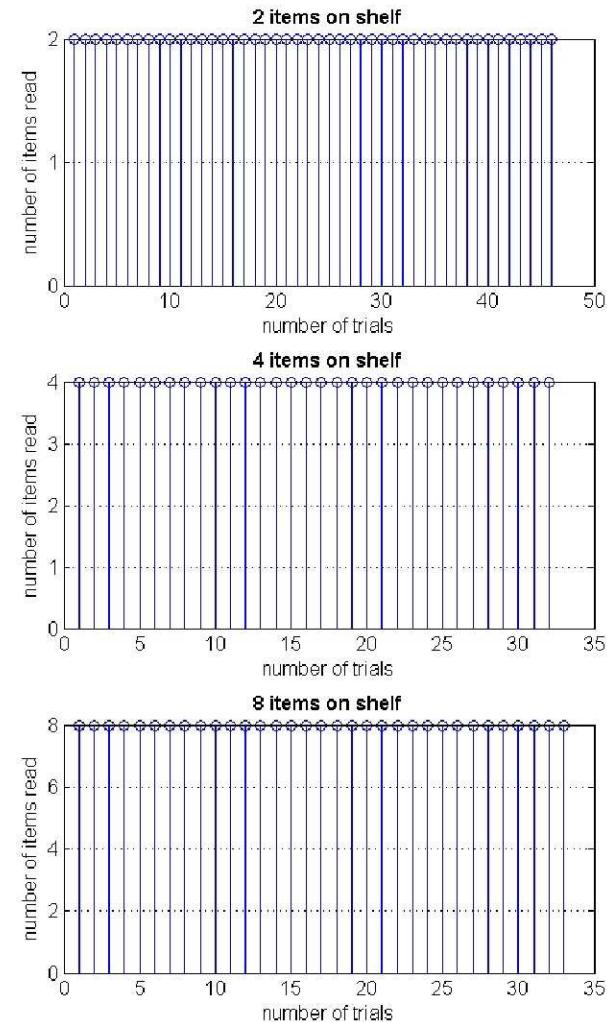
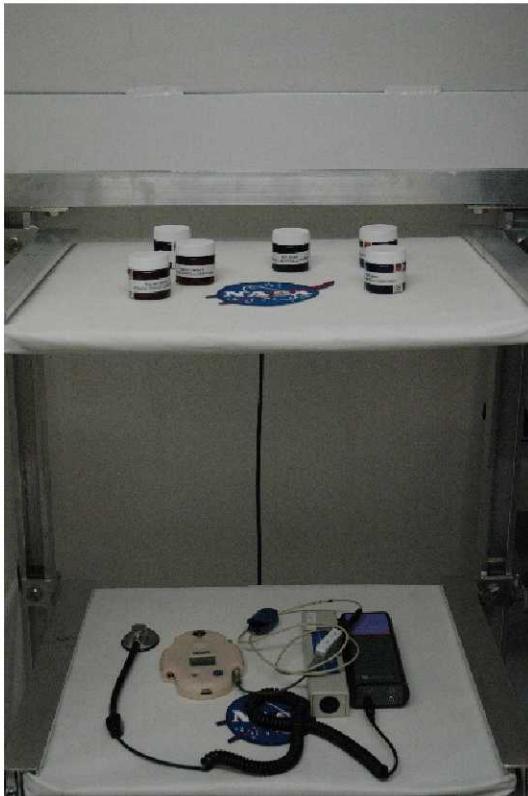
	Avg. front	Avg. right	Avg. left
Item level	75.5%	75.3%	75.7%
Ziplock level	95.1%	94.7%	93.7%

accuracy vs.  
operation mode

	Avg. (triggered)	Avg. (continuous)
Item level	76%	75%
Ziplock level	95%	94%



# RFID “Smart” Shelves and Receptacles





## RFID “Smart” Shelves and Receptacles

- **RFID reads on densely packed containers difficult**
  - high metal /liquid content esp. challenging
- **RFID smart containers can provide supplemental inventory data**
  - smart shelve: additive (log items into database as added)
  - smart trash can: reductive (remove items from database as containers discarded)
- **Testing of RFID trash can indicates near-100% read accuracy**
  - Ziploc bags, food vacuum packs, conductive drink pouches, battery packs, pharmaceuticals, etc.
- **Work on zero-g RFID trash can in progress**

